Acquisition Directorate

Research & Development Center

Report No. CG-D-01-18

Oil in Ice Project Final Report

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Revised March 2018

Homeland Security

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Technical Report Documentation Page

1. Report No.	2. Government Accession Number	3. Recipient's Catalog No.
CG-D-01-18		
4. Title and Subtitle Oil in Ice Project Final Report		5. Report Date Revised March 2018
		6. Performing Organization Code Project No. 4701
7. Author(s) Kurt A. Hansen and Dr. Michele Fitzpatrick		8. Performing Report No. RDC UDI # 1567
9. Performing Organization Name and Address Shearwater Systems, LLC Contractor for USCG Research and Development Center 1 Chelsea Street New London, CT 06320	U.S. Coast Guard Research and Development Center 1 Chelsea Street New London, CT 06320	10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Task Order #HSCG32-16-J-500019
12. Sponsoring Organization Name and Address COMMANDANT (CG-MER) US COAST GUARD STOP 7516 2703 MARTIN LUTHER KING JR AVE SE WASHINGTON, DC 20593		13. Type of Report & Period Covered Final
		14. Sponsoring Agency Code Commandant (CG-MER) US Coast Guard Washington, DC 20593

15. Supplementary Notes

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16. Abstract (MAXIMUM 200 WORDS)

In the northern regions of the United States, the Coast Guard (CG) and Environmental Protection Agency (EPA) are required to respond to oil spills during the winter months. The majority of the spills are tank leaks and gasoline truck accidents that may occur near waterways; thus, the oil can reach navigational waters, such as harbors and rivers, requiring CG response. The reduced ice during some seasons may increase vessel and barge traffic and increase the potential for more accidents. Given the potential increase in risk of oil spills in colder weather with ice-packed waterways, The CG needs better technologies for responding to oil spills in these extreme cold weather environments both in the Arctic and the northern contiguous United States.

The overall project objective was to provide planners and responders, both inside and outside the Coast Guard, with useful spill response information. Over the past seven years, the CG Research and Development Center has conducted a number of demonstrations of new technologies, approaches, and tactics to detect, track, and remove oil from ice-infested water in the Great Lakes and Alaska marine environment. This report describes the various field technology demonstrations and provides an appendix with a description of 11 tactics using the most promising response technologies.

The report has been reorganized and revised in March 2018 to reflect the historical events of the project demonstrations and final research recommendations.

17. Key Words	18. Distribution Statement		
Oil spills in ice, Great Lakes oil spill response, Arctic oil spill response, oil spill response demonstrations	Distribution Statement A: Approved for public release; distribution is unlimited.		
19. Security Class (This Report)	20. Security Class (This Page)	21. No of Pages	22. Price
UNCLAS//Public	UNCLAS//Public	58	

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EXECUTIVE SUMMARY

The anticipated reduction in ice during winter seasons may increase vessel and barge traffic, thus increasing the potential for accidents and oil spills in ice-laden waters. Given the potential increase in risk of oil spills in colder weather with ice-packed waterways, The CG needs better technologies for responding to oil spills in these extreme cold weather environments both in the Arctic and the northern contiguous United States. The overall project objective was to provide planners and responders, both inside and outside the Coast Guard, with useful spill response information. This report describes the various field technology demonstrations and provides an appendix with a description of 11 tactics using the most promising response technologies.

Starting with stakeholder workshops in Anchorage and Cleveland in 2010, the CG Research and Development Center (RDC) identified new technologies, approaches, and tactics to detect, track, and remove oil from ice-infested water in all conditions. The RDC then conducted a number of demonstrations in the Great Lakes and Arctic marine environments from 2011-2015. These demonstrations were conducted on Seagoing Buoy Tenders (WLBs) in the Great Lakes; off Alaska, Rhode Island, and North Carolina; and off the CGC Healy in the Arctic. Specific technologies demonstrated included unmanned aerial and underwater vehicles with cameras and sonar; an aerostat with visual and infrared cameras; remotely operated vehicles with cameras and sonar; multiple types of skimmers (brush, drum, rope mop), including skimmers designed for Arctic service; fire-resistant booms; and ship radar adapted to ice. During these demonstrations, commercial partners, federal partners, and CG responders deployed the equipment, while the RDC documented the advantages and disadvantages of each and recorded the lessons learned regarding how best to use each technology.

Three gaps were identified during the demonstrations: temporary storage of collected oil, ice management for skimmers, and personnel decontamination in cold weather on limited deck space. For temporary storage, the RDC found the use of a storage bladder towed alongside a skimmer vessel would be risky with ice in the water. RDC developed and evaluated two prototype temporary storage containers that could be mounted on the deck of a WLB. The tie-down method still needs improvement to reduce trip hazards, and a concept of operations needs to be developed concerning when and how to use these systems. Second, RDC realized through some testing performed by the Bureau of Safety and Environmental Enforcement (BSEE) that ice builds up in front of skimmer intakes, greatly decreasing their efficiency. An Ice Management System, called an "ice cage" and shaped like a cone, was designed and built. The ice cage was evaluated both during a field demonstration, and at BSEE's Ohmsett facility with oil. The system proved to keep ice pieces away from the inlet and increased efficiency; but, it also needs a concept of operations and some design refinement to aid in its assembly in cold weather on a WLB deck. Third, RDC noted that decontamination of personnel in cold weather, especially on vessels with limited deck space, was problematic. Normal wash-down methods using water would not work due to the cold, lack of storage for the effluent, and lack of deck space. Working with members of the CG National Strike Force, RDC developed and documented a process to accomplish decontamination without the use of water.

The demonstrations showed that some of the technologies, approaches, and tactics require additional research before they are ready to be used in the field. Unmanned underwater vehicle use and sensors need to be evaluated for detecting oil under ice; remotely operated vehicles need further evaluation to explore their fully utility; collection options for oil under thin ice require research; and skimmer operations in freezing conditions require further research to prevent pump and hose clogging. This project has advanced the state-of-knowledge in the entire response system by exposing many individuals and organizations to methods to mitigate oil in extreme cold weather environments. This knowledge will be useful for responding to spills in the future.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACS	Alaska Clean Seas
BSEE	Bureau of Safety and Environmental Enforcement
COP	Common Operating Picture
CG	US Coast Guard
CGC	Coast Guard Cutter
CRRC	Coastal Response Research Center
D1	US Coast Guard District One
D17	US Coast Guard District Seventeen
DECON	Decontamination
EO	Electro-optical
EPA	Environmental Protection Agency
ERMA	Environmental Response Management Application
FAA	Federal Aviation Administration
FOSC	Federal On-scene Coordinator
GPC	Global PCCI A Joint Venture Company
IR	Infrared
ISB	In-situ burning
kt	Knot
lb	Pound
LRB	Lamor Oil Recovery Bucket
MPT	Marine Portable Tanks
NM	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
NSF	National Strike Force
PPE	Personal protective equipment
PVC	Poly vinyl chloride
RDC	US Coast Guard Research and Development Center
ROV	Remotely operated vehicle
SORS	Spilled Oil Recovery System
STAR	Spill Tactics for Alaska Responders
SUAS	Small unmanned aerial systems
SUPSALV	US Navy Supervisor of Salvage
TST	Temporary storage tank
UMRBA	Upper Mississippi River Basin Association
USN	US Navy
UUV	Unmanned underwater vehicle
UV	Ultraviolet
VOO	Vessel of Opportunity
WLB	USCG Seagoing Buoy Tender

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1 INTRODUCTION

In the United States, the Coast Guard (CG) and Environmental Protection Agency (EPA) have the responsibility to respond to oil spills in our Nation's navigable waters. During the winter months, this can be particularly challenging in the extremely cold climates of northern U.S. areas, such as Alaska, the Great Lakes, and Northern New England. The lack of available knowledge, techniques, and technology appropriate for oil spill response in the icy waterways of these harsh environments puts the nation at risk of not being able to effectively and efficiency remove spilled oil from these waterways. Due to climate change, the amount and thickness of ice has declined over recent years in all three regions. The reduced ice may increase vessel and barge traffic, which could increase the potential for accidents and oil spills. In addition, the aging petroleum pipeline infrastructure is a cause for concern in the Great Lakes. The Arctic is also an emerging focal point for spill response planning and environmental protection, because of an expected increase in oil production (USCG, 2013).

1.1 Need

As outlined in the National Oil and Hazardous Substance Pollution Contingency Plan (40 CFR 300), the Coast Guard will lead efforts to plan for, and respond to, oil and hazardous materials in our Nation's navigable waters. Spill response in the Arctic presents major operational challenges due to: the distances involved in mounting a response in Alaska; limited infrastructure such as ports and airports; and the inherent difficulty of recovering oil from ice-covered waters. During the winter months in New England and the Great Lakes, responders must also deal with ice-covered waters. Spill response research for ice conditions has been limited: there was an increased emphasis in the 1980s, but the research has lagged since then.

Changing environmental conditions are requiring responders in Northern areas to re-evaluate the recommended equipment and techniques used to remove oil from waterways. For example, CG District One (D1) in New England had a cold-weather response workshop in 2007, and CG District Seventeen (D17) is initiating efforts to increase limited spill response capabilities on the North Slope of Alaska in anticipation of increased exploration, drilling, and shipping. There are tactics detailed in the Spill Tactics for Alaska Responders (STAR) manual for the Arctic (STAR, 2014) and through the Alaska Clean Seas (ACS) Technical Manual (ACS, 2015). However, most of these tactics have not been field tested, especially in the Great Lakes or New England. In addition, new detection and recovery technologies have been developed that are not addressed within these resources.

This project's objective was to research the response needs and requirements in both the Arctic and the Great Lakes and to identify those technologies, approaches, and tactics that would address those needs in both environments. This also includes the logistics needed to support the equipment and responding personnel. This report documents lessons learned from the CG demonstrations and development efforts, and makes recommendations for future research work.

1.2 Methodology

The CG Research and Development Center (RDC) began by using workshops and literature reviews to identify potential tactics and equipment that needed additional evaluation. Following these workshops, RDC then planned and conducted a number of demonstrations of existing response technologies and tactics to detect, track, and remove oil in ice-infested water under different conditions identified through the literature

reviews, market research, and workshops. Based on feedback from the initial demonstrations, the RDC developed equipment for temporary storage of recovered oil, ice management, and personnel decontamination for primary use on CG Juniper Class buoy tenders (WLB). The RDC documented lessons learned from demonstrating the response technologies and tactics in order to provide that knowledge to responders for planning and executing responses to oil spilled in ice-infested marine environments.

1.2.1 Scoping Workshops

In 2010, the RDC conducted two workshops with stakeholders in Anchorage and Cleveland to determine if lessons learned from conducting an evaluation of equipment and tactics in the Great Lakes during the winter would be applicable to the Arctic. During these workshops, participants also identified potential technologies and scenarios for evaluation. The resulting recommendation was to plan a series of Great Lakes demonstrations to evaluate selected technologies and supporting logistical needs. Conducting the demonstrations on the Great Lakes was desirable due to the significantly lower cost and the ease of obtaining needed logistics, as opposed to conducting the demonstrations in the Alaskan Arctic region (Hansen and Lewandowski, 2011; Coastal Response Research Center (CRRC), 2010; Softye and Comfort, 2010).

While Great Lakes ice and Arctic ice are different, there are climatic similarities when comparing the Great Lakes winter and the Arctic summer and shoulder seasons (fall and spring). The ice edge in the Arctic is usually composed of first-year ice, so it is very similar to the ice in the Great Lakes. Workshop participants also agreed that the challenge of removing oil from a broken and moving ice environment exists in both the Great Lakes and the Arctic. With these similarities, specific spill response tactics may be applicable to both environments.

Some differences between the two environments do need to be taken into account during planning and response. The greater amount of vessel traffic in the Great Lakes creates more of a risk for spills. The elimination of the use of dispersants and the limited window in time and space for in-situ burning (ISB) in the Great Lakes focus efforts on mechanical response under conditions when the ice may not support personnel and equipment. The location of major cities and transportation infrastructure in the Great Lakes region simplifies response logistics.

1.2.2 Great Lakes Oil-in-Ice Demonstrations

The RDC conducted three oil-in-ice response demonstrations in the Great Lakes from 2011-2013 that informed discussions about how to respond to oil in broken and loose ice conditions (Cooper and Dugery, 2011; RDC, 2012; Yankielun, et al., 2012; Yankielun, et al., 2013; Hansen, 2013).

The RDC demonstrated the following techniques and technologies in the Great Lakes using the references above:

- A newly-designed, grooved, drum skimmer fitted with a steam/hot water hook-up (2011). The manufacturer, ELASTEC, designed this concept to help reduce the viscosity of oil being collected, and minimize ice blockages;
- A fire boom that can be used to corral oil and ice (2011, 2012, 2013) when towed in a U-configuration using two small vessels;

- A fire monitor (also called a water cannon) used for “herding” oil into a containment boom. This demonstrated a viable method for diverting oil in broken ice for collection. (2011, 2012, 2013);
- An older-design, rope-mop skimmer, which uses sorbent ropes for picking up oil (2011, 2012);
- A Boom Vane, with an additional small drum skimmer (2011, 2012). The Boom Vane, controlled from shore, utilizes water current to hold a diversion boom in place, while the small skimmer operates in the pocket of the boom;
- A Helix skimmer that has brushes that function well in cold weather. It can be used with the Spilled Oil Recovery System (SORS; Figure 1) (2012, 2013);
- Slotting of a solid ice sheet to produce an oil collection area (2012);
- Remotely Operated Vehicle (ROV) used to visually search for oil under the ice and on the bottom of the waterway (2012, 2013);
- Unmanned Underwater Vehicle (UUV) used to search under the ice using an upward-looking sonar. (2013);
- Oil- and ice-detecting radar (2013);
- Aerostat balloon with electro-optical (EO) and infrared (IR) real-time video to provide local surveillance (2013);
- Containment boom deployment and recovery within the ice (2013); and
- A new type of bucket skimmer for oil recovery and ice management (2013).

Figure 1. CG buoy tender deployment of SORS skimmer.

1.2.3 Arctic Oil-in-Ice Demonstrations

The oil-in-ice response demonstrations conducted in the Arctic from 2012 through 2015 included technology demonstrated in the Great Lakes, as well as technology exclusively demonstrated in the Arctic (RDC, 2012; GPC, 2012; Hansen, 2012; Hansen, et al., 2014; Story et. al. 2015). The first Arctic demonstration included collaboration with the US Navy Supervisor of Salvage (SUPSALV). SUPSALV provided their spill response system, personnel and a tug/barge as a staging platform, and the CG Juniper Class buoy tender (WLB) SYCAMORE deployed the spill response system. Subsequent Arctic demonstrations involved deployments from the CG Cutter (CGC) HEALY and included logistical and personnel support and funding from the RDC project, “Arctic Operations Support”.

The RDC demonstrated the following technologies in the Arctic using the references above:

- Helix skimmer; concept for cold weather SORS deployed off a WLB (2012, 2013);
- High Speed Current Buster Skimmer, which is a skimmer in US Navy inventory in storage near Anchorage (2012);
- Boom Vane used to control the boom off the side of the WLB without a structural boom (2012);
- Polar Bear skimmer designed to handle ice conditions (2012; Figure 2);
- Small unmanned aerial systems (SUAS) to evaluate use for surveillance (2013, 2014, 2015);
- Remotely Operated Vehicle (ROV) to evaluate use for searching under ice (2013, 2014, 2015);
- Unmanned Underwater Vehicle (UUV); same vehicle as deployed in Great Lakes but in a harsher environment (2013, 2014);
- Aerostat for surveillance (2014, 2015); and
- Oil- and ice-detecting radar (2014, 2015).

Figure 2. Polar Bear skimmer deployed.

2 DEMONSTRATION RESULTS AND LESSONS LEARNED

The demonstrations described in this report provided valuable information for personnel responding to oil spills in ice conditions. This Section discusses the lessons learned from technologies and techniques used during the demonstrations.

2.1 Logistics

Responders in the Great Lakes region are generally used to responding on land. Many of the lessons learned and recommendations derived from the demonstrations reflected a lack of experience operating in the cold Great Lakes open-water climate. In addition, there are limited platforms in the region that can support operations on the water in ice conditions, and most of these platforms are Coast Guard assets.

In remote areas of coastal Alaska, there is little to no infrastructure, and marine-based logistical support will be the only way to support long-term, on-water oil recovery operations. The Arctic demonstrations reinforced the main issues dealing with remoteness and lack of supporting infrastructure on the North Slope of Alaska, including lack of deep water ports, lodging for response personnel, and limited warehouses/storage and disposal facilities (Hansen, 2014).

Logistics Lessons Learned:

- Icebreaker assistance may be necessary to enable response vessel's transits through ice to the oil.
- Environmentally-safe de-icing methods are necessary to ensure no hazardous liquids get into the water.
- Frequent on-deck crew rotations are necessary in cold weather.
- Shipping and loading equipment in cold climates is easier if everything is containerized.
- The use of barges can present both unique challenges and opportunities not found on self-propelled vessels. Planners need to develop procedures for using and tending barges in ice and cold weather conditions during emergency oil spill response.
- There are few vessels built to operate in ice conditions. Responders may need to adapt available equipment and tactics to these less capable types of vessels.

2.2 Detection and Surveillance

Before spill responders select tactics and deploy equipment, spill management personnel must first have a clear picture of the geographic extent and movement of the spilled oil. The National Oceanic and Atmospheric Administration's (NOAA's) Environmental Response Management Application (ERMA) is an online mapping tool that integrates both static and real-time data, and may be a candidate for serving as the Common Operating Picture (COP) to display information including surveillance data. This capability contributes to the development of mapping and projecting spill trajectories.

In order to build a COP, sensor data are needed. The RDC successfully demonstrated two unmanned aerial sensor platforms, the tethered Aerostat and the remotely operated SUAS (Sec. 2.2.1 and 2.2.2). Additionally, these demonstrations included two underwater technologies, the ROV and the UUV (Sec. 2.2.3 and 2.2.4). The RDC successfully demonstrated the ROV. The UUV needs additional evaluation for the oil in ice application. A fifth demonstrated technology was a radar designed to detect oil and ice (Sec. 2.2.5). It successfully found openings in the ice; however, further development is needed to find oil among the ice.

2.2.1 Aerostat

The RDC deployed a small helium balloon system, called an Aerostat, in both the Great Lakes and the Arctic as a possible detection and surveillance system (Figure 3). During the 2013 Great Lakes demonstration, the remote-control tilt/pan/zoom real-time EO and IR sensors both provided excellent situational awareness of the operational scene when the receivers were within line-of-sight. Figure 4 shows Aerostat sensor output on the CGC HOLLYHOCK (Yankielun, et al., 2013).

In 2014 and 2015, the RDC launched the Aerostat in the Arctic in various weather conditions and with a wide range of payloads and mission objectives. Operational tests resulted in establishing Arctic procedures,

as well as safe operational parameters for Aerostat flight operations in the Arctic (Hansen, et al., 2014 and Story et.cl. 2015).

Figure 3. Aerostat being deployed from the CGC HEALY.

Figure 4. Aerostat sensor output on CGC HOLLYHOCK.

Aerostat Lessons Learned:

- Visibility and wind speed are the main limiting factors with utilizing the Aerostat.
- Nearby structural effects on wind direction, velocity, and especially turbulence/eddies must be considered when launching.
- Use in cold conditions can require additional helium, due to the increased atmospheric density at the lower temperatures.

- Providing different sensor systems and balloon configuration options, depending on conditions, will make deploying the Aerostat system more useful. This involves selecting a system for surveillance and deployment that can operate in various wind and visibility conditions, such as a radar system that can operate in fog. Sensor and aerostat vendors can offer these alternatives.
- An instrument that can handle the moisture (i.e., has the ability to keep the lens clear and ice free) would increase capability.
- Situational awareness of where the balloon and tether are located is essential due to wind shifts, crane operations, and other possible interferences on board.
- Multiple receivers can be distributed to other assets and/or command posts that are in the line-of-sight of the aerostat, so that all participants can watch developments in real time.

2.2.2 Small Unmanned Aerial Systems (SUAS)

During the Arctic Shield 2013 spill response exercise, the highlight event was the RDC launching the SUAS from CGC HEALY's deck (see Figure 5) and recovering it from the water or ice sheet (Hansen, et al., 2014).

Figure 5. SUAS being deployed from the CGC HEALY.

In 2014, a net-capture system was developed and successfully used on the CGC HEALY. This allowed the operator to fly the SUAS into a net deployed for recovery; rather than landing the SUAS in the water, on sheet ice, or on the vessel deck. During this demonstration, the RDC used the SUAS to detect and map ice floes and oil surrogates from the air (Hansen, et al., 2014).

In 2015, the SUAS accomplished several demonstration tasks that can pave the way for increased and more effective SUAS-shipboard operations. The RDC successfully tested SUAS in: beyond-line-of-sight operations; autonomous net capture onto the forecastle of the ship; and autonomous net capture onto the flight deck of the ship. They were also able to live-stream video to the ship and back to shore for viewing over the internet from any location (Story, et. al., 2015).

At the time of this report, the RDC is the only Coast Guard organization to have purchased and flown SUASs. Use of a Small Unmanned Aerial System (SUAS) can enhance oil recovery by providing real-time

information to on-scene responders and the Incident Command Center. Types of sensors mounted in an SUAS depend upon lift capacity and weather conditions. Most surveillance packages include EO and IR cameras, although use of radar and communications systems as radio links are also possible. Due to flight restrictions, The RDC only demonstrated SUASs during the Arctic demonstrations. Once permitted for CG operations, the governing policy for SUAS will fall under the Air Operations Manual. The Federal Aviation Administration (FAA) has three different avenues for using drones. First, is a Certificate of Waiver or Authorization (COA); second, a Memorandum of Understanding used by government agencies; and third, the recently-released 14 CFR 61.107 – Remote Pilot Operations for SUAS (this process is focused on civilian uses). The FAA regulations for SUAS can be found at the following website: https://www.federalregister.gov/documents/2016/06/28/2016-15079/operation-and-certification-of-small-unmanned-aircraft-systems .

SUAS Lessons Learned:

- Deck or net landings are preferred as they alleviate the need to deploy a small boat to collect the SUAS.
- Additional development and testing are needed to enable consistent and reliable operations, especially in harsh environmental and icing conditions.
- Establishment of a link to ERMA can be difficult in the Arctic. It is dependent upon a number of factors, including atmospheric conditions and geographic location.
- The lack of accurate weather forecasting, combined with marine and ice fog, made launching within required FAA parameters very difficult. The restrictions on launch envelopes and landing parameters are still arbitrary. These limitations are more stringent than the limitations on manned aircraft.
- One of the advertised advantages for unmanned systems is that they can keep people out of harm's way. That is currently not possible with the SUAS, as the manned helicopters from the Forward Operating Location were able to launch in conditions that are out of tolerance for the SUAS.

2.2.3 Remotely Operated Vehicles (ROV)

The RDC deployed Remotely Operated Vehicles (ROVs; Figure 6) in both the Great Lakes and the Arctic as possible detection and surveillance systems. In the Great Lakes (2012), the ROV, with an ultraviolet (UV) fluorometer sensor package, showed great potential both as a means of locating oil concentrations under sheet ice and as a means of positioning and manipulating oil recovery equipment beneath the ice (Yankielun, et al., 2012).

ROV Lessons Learned:

- An ROV is a versatile platform that can handle many different payloads, such as cameras, sonar, and laser fluorometer.
- ROV operations can be successful in an oil-in-ice scenario. However, possible fouling of camera lenses and tethers will be a challenge.
- Cold weather may adversely impact ROV operations, including the mechanical aspects of the ROV itself, which could include problems with the thrusters and cable handling. The weather also exposes the operator and control station to harsh conditions.
- Set-up and deployment of the ROV require a clear deck space, depending upon the size of the system.
- RDC recommends that the main propulsion of the host vessel be shut down to prevent the ROV tether and control cable from fouling the vessel's propeller. Instead, use a vessel with a bow thruster,

or have the vessel moor against the ice. Options to counteract the effects of the wind during launch of the ROV include launching from the bow or the stern, depending on vessel orientation to the wind.

- The ROV operator needs situational awareness with respect to the constantly-moving ice. Tether pull can be affected by ice and slush movement around the tether, making underwater ROV control more difficult.
- Consider protective shields or 'armoring' for sensors to prevent damage from ice or handling.
- Depending on size, an ROV can be deployed and recovered without a crane. However, a crane would provide added safety in rough conditions.
- A light may be required on the ROV for use with a camera when thicker ice is present or during darkness.
- The laser fluorometer, designed to detect oil beneath the ice, was mounted on the top of the ROV and pointed upwards. This sensor was overloaded by sunlight at a depth of less than 10 feet.
- Use of sophisticated sensors requires a more stable platform. This requires using either software, to acquire the collected data and compensate for motion, or a larger ROV.
- Moving components (e.g., camera pan/tilt/focus mechanism) should be de-iced prior to deployment into the water.

Figure 6. ROV deployed in a water pocket near the ice sheet edge.

2.2.4 Unmanned Underwater Vehicles (UUV)

The RDC deployed Unmanned Underwater Vehicles (UUVs; Figure 7) in both the Great Lakes and the Arctic as possible detection and surveillance systems (Yankielun, et al., 2013; Hansen, et al., 2014). Use of a UUV can assist oil recovery by finding potential oil locations under the ice, gathering bathymetry data, and detecting the presence of wildlife.

Figure 7. UUV being deployed.

UUV Lessons Learned:

- The vehicle demonstrated the potential for autonomous under-ice operation and data collection.
- The upward-looking capability would be useful in searching for oil under the ice where an ROV could not reach. However, the data is not available in real-time, as the system cannot communicate from beneath the ice.
- Systems should be easily deployable and recoverable without the use of small boats, especially in broken ice.
- Additional buoyancy adjustments are required when used in fresh water and in different salinity conditions.
- Most commercial systems are not designed for spill response operation. They may be susceptible to oil and ice damage, are not easily reconfigured, and data may take extra time to download.
- The number and weight of sensors that can be mounted depend upon the UUV's size, buoyancy, and battery capabilities.
- The amount of battery life controls the length of missions; also, the batteries needed to be in a warm environment (over 55°F) to charge.
- Decontamination techniques need to be developed for the UUV and the specialized equipment mounted on it.

2.2.5 Oil Spill and Ice Detection Radar

The RDC deployed the Rutter oil spill detection and ice detection radar in both the Great Lakes and the Arctic. In both the Arctic and the Great Lakes (Yankielun, et al., 2013; Hansen, et al., 2014), it clearly displayed areas of open water, as well as a variety of ice types (e.g., solid plate, rubble, and windrow features) that were not discernible on the vessel's navigation radar (Figure 8). Since there was no actual oil spill, the RDC could not demonstrate the system's ability to detect and identify oil.

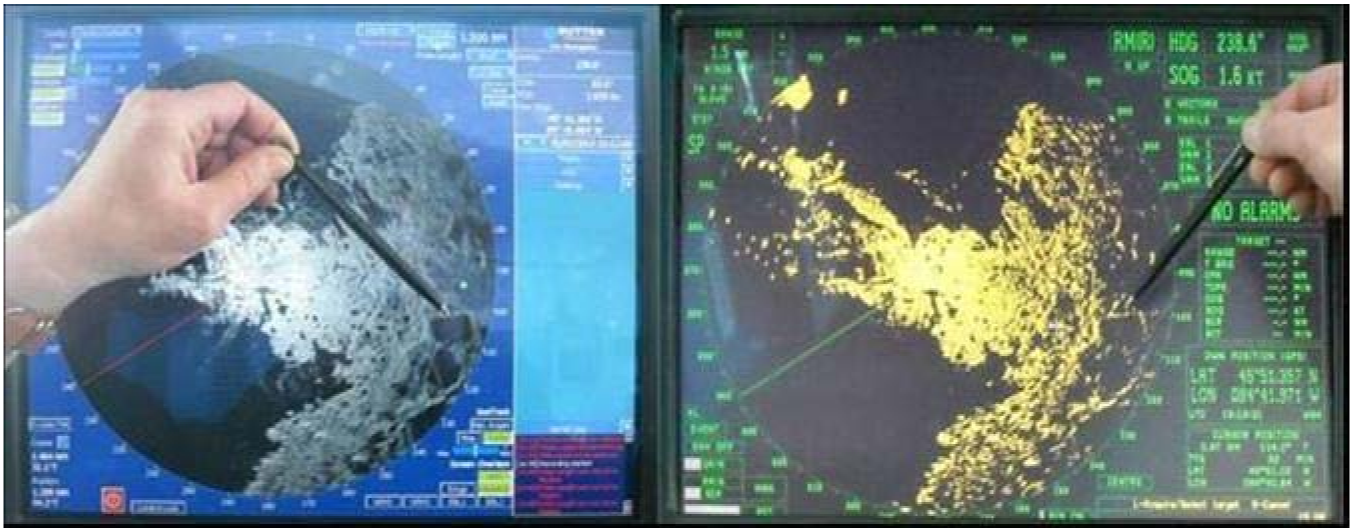

Figure 8. Comparison of ice radar (left) and standard navigation radar (right).

Oil and Ice Radar Lessons Learned:

- The ice radar clearly identified open water vs. ice coverage up to a range of three nautical miles (NM). The data collected indicated that the extra processing provided by the ice navigation radar enabled the crew to identify different types of ice and determine approximate thicknesses of different ice types.
- A longer-range (>4 NM) radar that could clearly identify ice locations, as well as display and identify different ice types (i.e., plate, rubble, windrow, etc.), would be helpful.
- The Rutter system provided a significantly higher level of detail of the lake's ice surface conditions than the standard navigation radar did for ice navigation and ice type identification.
- The ice radar could be used to find openings in the ice where oil could potentially pool.

2.3 Containment and Recovery

Different containment and recovery systems and tactics are necessary for various environmental conditions. This section focuses on lessons learned associated with operating oil spill response equipment near the ice edge and within broken ice.

2.3.1 Ice Edge Conditions

For the purposes of this report, the ice edge is defined as any place where there is a direct transition from solid or sheet ice (greater than 70% ice cover) to open water (less than 30% ice cover) with a minimal amount of broken ice in the transition zone.

2.3.1.1 *Skimming – Boom Vane*

When using booms and skimmers, mechanical containment and recovery near the ice is similar to that in open water, except for the additional need for safe operation of the equipment close to the ice. The boom vane is a newer technology that assists with boom use near the ice edge. It uses a series of vertical plates within its structure, which are submerged during operations, to develop a hydrodynamic force that pulls the

end of the boom into the current. This system will work when the current is parallel to the ice edge or when deployed from a forward-moving vessel.

In 2011, the RDC demonstrated the boom vane in the Great Lakes (Cooper and Dugery, 2011) in ice-free waterways. In the Arctic in 2012 (GPC, 2012; Hansen, 2012) it was used with the US Navy's (USN) SUPSALV Current Buster (SK0050) system. The unit was deployed from the deck of the CGC SYCAMORE (Figure 9) at current encounter rates (current plus ship speed) of up to 3 knots during this demonstration.

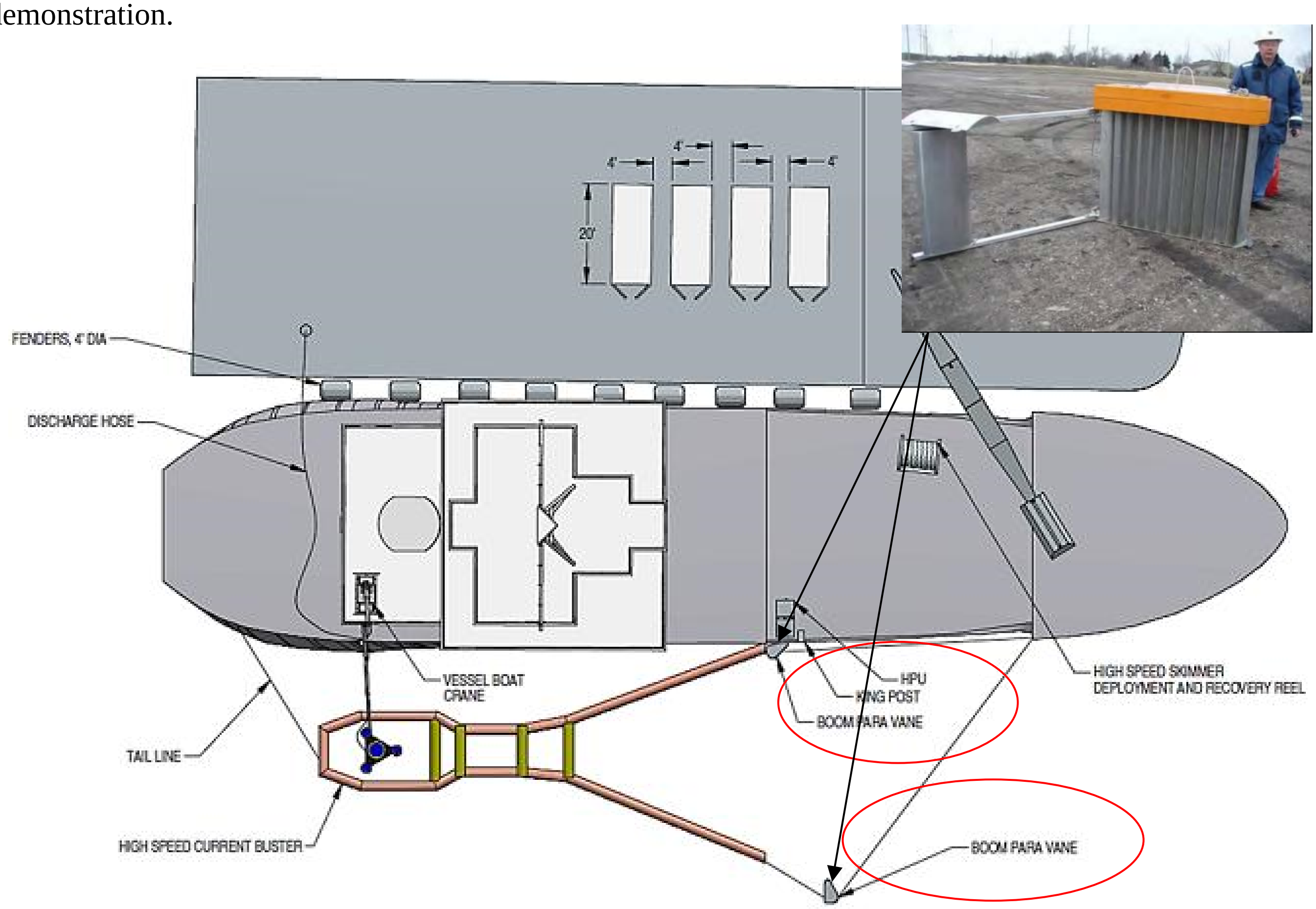

Figure 9. Overhead layout of current buster with boom vanes.

<u>Boom Vane Lessons Learned</u>:

- The boom vane displayed a great deal of potential in oil clean-up in ice conditions, as it can control the end of the boom to reduce the amount of ice collected.
- The boom is deployed, using the boom vane, to divert oil to a clean-up area. The boom vane can move the boom out of the path of the ice when broken ice threatens the boom.
- The boom vane can be used in selected areas where a vessel is not available for fast boom deployment.
- The boom vane requires currents greater than 1 knot to operate. A loss of precise steering control will result from slower currents.

- The boom vane can be used in current or towing operations up to 6 knots in optimal environmental conditions.
- This device would probably not be very useful in medium-to-heavy ice conditions where the ice could not be avoided.

2.3.1.2 *Herding with Fire Monitor/Water Cannon*

Using a high-pressure water stream or jet from a fire monitor/water cannon can be effective for herding both oil and broken ice (Figure 10). The fire monitor can be either self-contained or integral to the vessel. In ice-covered or partially ice-covered waterway conditions, this method should be quite successful in moving surface oil towards containment devices or skimmers when deployed from either a floating or fixed location. Fire monitors/water cannons can also aid in the herding of broken ice on the water surface, to keep the ice from interfering in oil recovery operations (Cooper and Dugery, 2011; RDC, 2012; Yankielun, et al., 2012; Yankielun, et al., 2013; Hansen, 2013).

Figure 10. Herding of oil substitute.

<u>Herding Lessons Learned</u>:

- Using the single-center, large water cannon on a tug works better for open water herding than using the two smaller side cannons on a tug, because the two smaller cannons counteracted each other.
- The stern-mounted water cannon provided maneuvering challenges for the tugboat skipper due to the obstructed view from the bridge to the tugboat stern. The consensus from the monitor operators and tug skipper was that a bow-mounted fire monitor configuration would improve herding effectiveness.
- Multiple vessels with fire monitors would be much better for herding oil in the open water as this provides more flexibility to approach the oil from different directions.
- Use of a boom on the outboard side of the barge could help concentrate any oil that is herded.
- Booms may be placed parallel to the ice edge, if the edge is not well defined and deep enough, in order to corral the oil.
- Herding towards an ice edge facilitates oil collection.

- Arching spray from fire monitors appeared to be more effective for herding than a strong, directed steady stream.
- One drawback to the fire monitor pack demonstrated in 2013 was its 3,450 lb. weight, which limits it to larger vessels and requires a crane to maneuver the package. Fire monitors and hoses already installed on vessels should generate similar herding results. Any vessel using such a system would require adequate displacement to counter the thrust imposed by the water stream.

2.3.1.3 *Vessel Slotting*

Maneuvering a vessel bow or stern into the edge of an ice sheet creates an ice/vessel 'pocket' for herding and skimmer recovery of oil. In the Great Lakes, the CGC HOLLYHOCK experimented with its ice-breaking capabilities to cut channels and pockets into the ice for oil collection (Yankielun, et al., 2012). Figure 11 shows a channel cut into the sheet ice and a side pocket running at an acute angle to the main channel after the ship has backed out. This ice-breaking effort produced an area of open water into which the RDC deployed the skimmer (Figure 12).

Figure 11. Channel or 'slot' created in sheet ice to facilitate oil skimmer deployment.

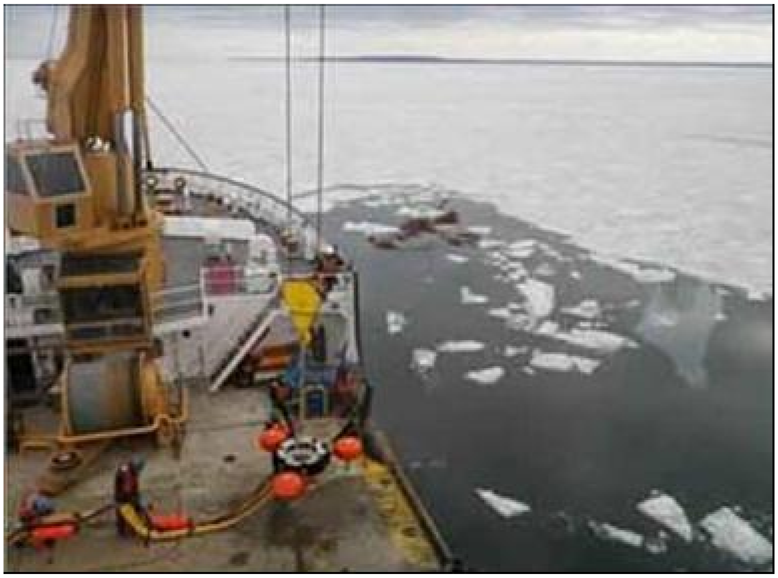

Figure 12. Helix skimmer being prepared for deployment in open water pocket.

Slotting Lessons Learned:

- An ice-capable vessel can utilize slotting tactics adapted from solid ice maneuvering techniques only if the ice mass is relatively stable and does not close the slot created.
- Responders must monitor changes in direction of wind and current, and adjustments made as needed, as the slot may open or close depending upon conditions.

2.3.2 Broken/Rubble Ice Conditions

Containment and recovery systems may be useful in the broken ice environment, where the ice serves to contain and concentrate oil in leads if the equipment is robust and deployed correctly. For the purpose of this report, broken ice includes ice coverage between 30% and 70%. At 70% concentration, ice is a significant impediment to skimming, with most skimmers having dramatically lower rates and efficiencies in the denser ice compared with the 30% ice.

2.3.2.1 *Skimming in Broken Ice*

Equipment for oil recovery in or near broken ice may be difficult to deploy and operate because of ice interfering with the boom and skimming system. Oil recovery systems deployed in broken ice need to be highly maneuverable, utilizing vessels that can safely operate in ice. Sometimes ice leads can act to contain and concentrate oil for collection by a recovery system.

2.3.2.1.1 Rope Mop Skimmer

Rope mop skimmers have historically proven successful in collecting oil along slots cut in solid ice, when oil has migrated under ice sheets. The RDC briefly deployed a rope mop skimmer with multiple mop ropes in the Great Lakes (Yankielun, et al., 2012; Figure 13).

Figure 13. Rope mop skimmer deployed in open water pocket.

Rope Mop Lessons Learned:

- Deploying the rope mop in high winds is difficult and possibly results in suboptimal performance due to a 'sail effect' deflecting the exposed portion of the mop belt.
- The rope mops should have a breakaway device or weak-link point to prevent the system from being damaged or pulled into the water if a rope mop hangs up on a large piece of ice.
- The rope mops can become tangled, and untangling them safely and quickly is important. This action may be difficult when the ropes are coated with oil.
- The RDC was concerned with how messy the collection could be, given the design of the rope-squeezing mechanism and the integrated collection tray under the motor. This could not be fully evaluated since oil was not used during these demonstrations.

2.3.2.1.2 Heated Grooved Drum Skimmer

In 2011, the RDC briefly deployed a grooved drum skimmer with a steam/hot water hook-up in water without ice in the Great Lakes (Cooper and Dugery, 2011) RDC also briefly deployed the system again in 2012 in the Great Lakes and among broken ice (Figure 14; Yankielun, et al., 2012). This device worked well at Ohmsett (SL Ross and MAR, 2013), but had problems during these field demonstrations with the steam line freezing overnight. It was also not as useful within the ice cage prototype, a cage that protects the skimmer from ice fragments that may reduce its performance (see Sec 3.2), when tested in ice at Ohmsett (Hansen and McKinney, 2016).

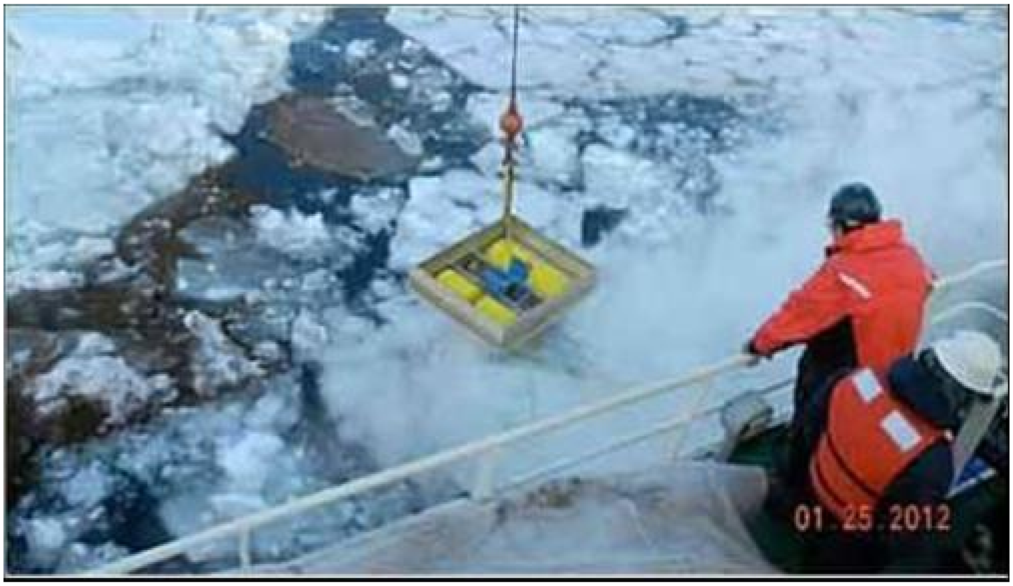

Figure 14. Drum skimmer deployed in rubble ice.

Drum Skimmer Lessons Learned:

- The drum skimmer may be too light to properly settle into a field of rubble ice and function efficiently.
- The drum skimmer may not be sufficiently armored for use in heavy rubble ice conditions.
- The pumps need to be fully primed to remove air bubbles from the water and steam lines.
- When using the ice cage, the drum skimmer does not create enough current to draw in the oil from the perimeter of the cage.

2.3.2.1.3 DESMI Helix Brush Skimmer

The DESMI Helix brush skimmer is included as a part of the CG's Spilled Oil Recovery System (SORS) inventory. In 2012 and 2013, the RDC successfully deployed the DESMI Helix skimmer in the Great Lakes and the Arctic under a variety of conditions including rubble and sheet ice. The Arctic demonstration in 2013 included an improved hose recovery system (Figure 15) that reduced the size and weight, did not permit the hose to drop onto the ice, and prevented the hose from collapsing and freezing up (Hansen, et al., 2014).

Figure 15. CGC Healy deploying Helix skimmer.

<u>Helix Skimmer Lessons Learned</u>:

- The manipulation and positioning of this skimmer worked best when slung from the vessel's bow-mounted 750-pound crane block.
- The Helix fittings, hoses, and moving parts should be ruggedized or armored to protect against rubble ice. Specifically, consider using armored hoses and hydraulic line sections where direct contact with rubble ice may cause puncture or severing.
- In addition, a sling or festoon configuration might help suspend and support the hoses to prevent contact and damage from floating ice.
- An ice management system would help to keep ice away from the skimmer.

2.3.2.1.4 <u>DESMI Polar Bear Brush Skimmer</u>

In 2012, the RDC briefly deployed the DESMI Polar Bear skimmer in the Great Lakes (Yankielun, et al., 2012). It appeared to be rugged and designed to withstand the broken ice conditions encountered.

In 2012, the RDC also deployed the Polar Bear skimmer in the Arctic over the side of the CGC SYCAMORE among some variable-sized drifting ice (GPC, 2012; Hansen, 2012). This provided experience for the buoy tender crew in executing this type of deployment.

<u>Lessons Learned for Polar Bear Skimmer</u>:

- A safety concern with this skimmer was that personnel needed to climb on top of the skimmer's frame to complete connections, which could be hazardous in icy conditions.
- The CG WLBs, alone, could not deploy either the Helix or the Polar Bear skimmers because a large amount of deck space is needed for getting the equipment out of the hold and for assembly. While the actual operation of the skimmers can take place on the WLB, the CG would potentially need an additional barge or vessel to provide the additional deck space to assemble the skimmer systems.

2.3.2.1.5 Lamor Oil Recovery Bucket

The Lamor Oil Recovery Bucket (LRB) is a brush-wheel skimmer operated from an excavator or from an on-board crane (Figure 16). For a 2013 Great Lakes demonstration (Yankielun, et al., 2013), the RDC operated the LRB from fixed mounts on the deck of the barge. From its hard-mounted, tie-down position at the bow of the barge, the skimmer demonstrated its operation by recovering peat moss, which was used as an oil simulant, from a pool of open water surrounded by broken ice.

Lessons Learned for LRB:

- Position of the skimmer on the barge or vessel could limit its use. For example, if the barge is sitting alongside of the ice edge, the skimmer needs to be mounted on the outboard side of the barge in the direction that the oil is approaching.
- All-in-one design (integrated skimmer head, hydraulics, and controller) reduces the number of components but increases the overall weight of the equipment. A large crane or other loading mechanism is needed.
- The use of an oil recovery bucket/boom assembly, securely mounted to the deck of a towed barge, works well in these circumstances in terms of maneuverability while providing deck space and storage.

Figure 16. Lamor oil recovery bucket.

2.3.2.2 *Herding and Ice Management*

As discussed earlier, using fire monitors for herding may aid in the movement of broken ice on the water surface, keeping the ice from interfering in oil recovery operations.

In 2013 on the Great Lakes (Yankielun, et al., 2013), the LRB demonstrated the ability to use its articulated arm to move small plates of ice out of the way to create an open water pool to collect oil simulant peat moss in conjunction with herding techniques (Figure 17). The herding tactic selected for this system was dependent on the skimmer's location on the barge: it needed to be located in an area that would permit the skimmer access to the water/oil.

Figure 17. LRB demonstrating ability to push ice out of way.

2.4 In-situ Burning

In-situ Burning (ISB) is a technique used in offshore operations to remove oil from the surface of the water before it reaches the shoreline. Two vessels must capture the oil in a boom and tow it to a safe location while moving at a speed of less than 1 knot (kt) to avoid the oil from escaping the boom. Broken ice conditions may complicate vessel operations and fire resistant boom deployment where booming is necessary to concentrate the oil.

In 2012, the RDC conducted demonstrations in the Great Lakes to see if fire-resistant booms designed for ISB (generally called fire booms) could successfully be deployed in broken ice conditions (Yankielun, et al., 2012). While the RDC did not conduct actual burns, previous tests have shown that oil will burn in the presence of broken ice (Potter, 2010). The Great Lakes demonstration was to show how the vessels could maneuver and collect ice that theoretically would have oil between the pieces. The RDC attempted several approaches into a broken ice field using a fire boom in various configurations to determine which technique would be the most effective in corralling both the oil and the ice. The traditional ‘U’ shape did succeed in collecting some broken ice but the boats had trouble maneuvering together. Another method explored used a ‘J’ configuration, where one vessel is slightly ahead of the other (Figure 18). Once the vessels were clear of the ice edge, they maneuvered into the “U” shape configuration. During several attempts to use this process, RDC observed that of the initial “bite” of broken ice the boom removed from the broken ice pack, between 70-85% of the initial volume of ice stayed in the boom once the ice pack was cleared. RDC also observed that the amount of broken ice and the size of the ice pieces play a role in the success of the boom, and operators need to adjust tactics depending upon vessel and boom capabilities.

Figure 18. Fire Boom (PyroBoom^{TM}) deployed and towed by two tugboats to simulate collection of oil in rubble ice.

ISB Lessons Learned:

- Fire-resistant boom appeared to hold up well while gathering and towing ice.
- Close coordination between both vessels is important for successful deployment of the boom in open water and for entry of boom into the ice.
- Two vessels of sufficient horsepower with ice-breaking capability are required for effective deployment and manipulation of the boom.
- Boom can be deployed by allowing it to slide off the vessel deck, or it can be deployed in sections, if the vessel has an onboard crane.
- Broken ice coverage of 40-50%, with ice pieces no larger than 5 feet (1.5 meters), appears to be the limit for collecting an oil/ice mixture for in-situ burn. Thicker and greater concentrations of broken ice and larger floes caused the fire-resistant boom to ride over top of the ice.
- Use of a ‘J’ boom formation, rather than the traditional ‘U’ formation, appears to make it easier for the vessels to control the amount of ice captured.
- To retain the ice in the ‘pocket’ of the boom, the towing speed had to be kept to a minimum. The ability of the tugboat to operate at a slow speed makes it ideal for the process, as opposed to a vessel that must continually clutch its prop in and out to limit headway.
- Any type of boom used with this tactic must be able to withstand being dragged over short sections of ice; but, it should be deployed and retrieved in open water.

3 RDC DEVELOPMENT EFFORTS

Based on gaps identified during the initial field demonstrations, the RDC pursued three technologies and techniques identified as needing additional development for use on a CG buoy tender or a vessel of opportunity (VOO). These were the Temporary Storage Tank (TST), Ice Cage (also referred to as “Ice Management System”), and Cold Weather Decontamination (DECON).

3.1 Temporary Storage Tanks (TST)

3.1.1 Initial Development

An important and limiting factor in effective containment and recovery operations is the availability of storage for the recovered oil on the skimming vessel. This was identified as a gap since typical bladders or non-ice hardened barges towed along the side of the vessel could be punctured by the ice. The CG Juniper Class Seagoing WLB has deck space for temporary storage containers (Marine Portable Tank (MPT)). One was deployed in the 2012 Great Lakes demonstration (Figure 19). Each MPT had a storage capacity of approximately 4,200 gallons. During the Deepwater Horizon response, the Coast Guard developed a preliminary layout for simultaneously deploying four of these tanks. However, a detailed mounting and plumbing design is needed for cold weather use.

Figure 19. A temporary storage tank mid-deck on a Juniper Class Seagoing WLB.

RDC worked with ELASTEC American Marine to develop a collapsible tank that can be stored in the same manner as the current bladder. It consists of a bladder-like arrangement with internal baffles and external aluminum support poles (see Figure 20). It can hold close to 3,900 gallons. Multiple TSTs would be needed to meet the Lancer Barge capacity currently in the CG's National Strike Force's (NSF) inventory. During an initial 2014 pier side demonstration on CGC JUNIPER, RDC and ELASTEC filled the collapsible TST with water to evaluate the initial strength and stability (ELASTEC, 2014). RDC identified the following minor issues for improvement to a future system: the material used for the manhole should be converted from aluminum to plastic to be lighter and survive better; the survivability of the selected material in cold weather was questioned so another material was suggested; and the hooks used to connect the straps onto a WLB need to be reduced in size in order to fit correctly.

Figure 20. Empty, collapsible TST ready for service.

3.1.2 Field Demonstration

The RDC deployed two, improved (i.e., collapsible) TSTs on the deck of the CGC JUNIPER during the August 2016 demonstration in Narragansett Bay (Figure 21). The first one was the system deployed in the first demonstration with minor adjustments for the manhole and tie-down arrangements. The second TST (black color in Figure 21) used a material better suited for colder weather and had a larger capacity of about 4,800 gallons (Balsley, et.al. 2016).

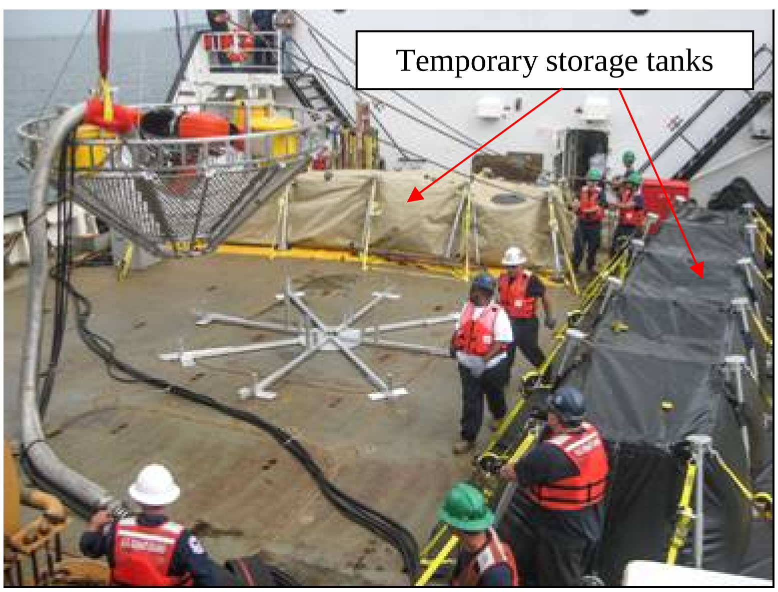

Figure 21. Two temporary storage tanks fully erected on the deck of the CGC Juniper during the underway demonstration.

3.1.3 TST Lessons Learned

The final field demonstration aboard the buoy tender, CGC JUNIPER, provided the following considerations for the development and implementation of TSTs:

- These TSTs were not fully evaluated for storing oil and should be subjected to additional tests in the future. The main concern would be whether the oil sloshing around cause damage to the system.
- Both TSTs required many small parts that would prove to be difficult to assemble in cold weather when wearing gloves.
- Once all the small parts were assembled, both tanks were easily set up. As a result, the RDC recommends that some parts come pre-assembled, to preclude handling small parts.
- TSTs that are packed and bound take up relatively little storage space (Figure 22) and can be placed in the WLB storage hold.
- The TST needs to use a manifold system between the skimmer and tanks to ensure tank fittings are not under stress when being pulled by the skimmer hoses.
- A better method is needed to secure the TST to the deck without causing trip hazards to workers.
- The size, weight, and center of gravity for these systems are within the limits for weight, size, and locations approved for use of the Marine Portable Tanks during the Deepwater Horizon spill response. Once final configurations and arrangements are determined, another analysis will be needed.
- Methods and configurations for the storage of these tanks in the ship's hold also need to be investigated.

Figure 22. Temporary storage tanks packed and bound.

3.2 Ice Management System (Ice Cage)

3.2.1 Initial Development and Tests in Ice

Results of the Great Lakes and Arctic demonstrations showed that lighter or vulnerable skimmers that have limited structure and exposed collection devices, might not remain intact when placed near ice. The RDC developed an ice cage designed to keep ice fragments from affecting skimmer performance (Marine Pollution Control, 2015). The design leveraged the results of the Bureau of Safety and Environmental Enforcement's (BSEE) earlier 2013 "Ice Month" testing at the National Oil Spill Response Research and Renewable Energy Test Facility (a.k.a. Ohmsett; SL Ross and MAR, Inc., 2013). Those test results showed that most skimmers could not pick up oil in pack ice of over 70 % coverage. This was due to pieces of ice interfering at the weir, brush, or belt interface with the water, and kept the oil from reaching the collection point. In March 2014, the RDC partnered with BSEE to evaluate RDC's ice management system at Ohmsett, using the Coast Guard's Helix skimmer. Test results appeared to triple the oil recovery rate in over 65% ice coverage (Hansen and McKinney, 2016).

3.2.2 Field Demonstration

During the August 2016 Narragansett Bay field demonstration, a strengthened ice cage was deployed with a DOP-Dual Helix skimmer provided by the CG Atlantic Strike Team (Figure 23; Balsley, et al., 2016).

Figure 23. Ice cage integrated with a DOP-Dual Helix skimmer.

<u>Ice Cage Lessons Learned</u>:

Although no ice was present during the August 2016 field demonstration, the RDC learned valuable lessons:

- The ice cage required its many parts to be assembled in a particular order. The RDC recommends a reduction in parts to make assembly easier in cold weather and reduce labor.
- A stand is required to hold the ice cage during assembly. RDC recommends reducing the size of this stand to create more deck space for the crew to maneuver.

- The chosen vessel should have the appropriate ice classification and crew to perform this operation.
- The vessel should have the ability to handle temporary storage of collected oil.
- The demonstration revealed the need for adequate deck space to maneuver the ice cage, since the first 25 feet of the hose is relatively rigid-braided stainless steel. This stainless steel, chemical-resistant hose is needed for cold weather as it ensures the hose will not freeze shut when not in use.
- Skimmer deployment may be difficult. Hydraulic hoses and recovery hoses may be susceptible to damage, if dragged over or through ice.
- Pieces of ice can block the oil from reaching the cage inlets.
- Certain skimmer configurations may need adequate water supply tanks, hoses, and heating systems.
- Long lengths of hose running over the deck may need to be heated to prevent freezing.
- Skimmers that use a tether system from the vessel and that deploy over the side either with or without a crane may present challenges in terms of maneuverability.

3.3 Personnel Decontamination (DECON)

Decontamination (DECON) involves the removal of oil or other contaminants from personnel or equipment after they leave a contaminated area (the Hot Zone) or working area. The purpose for personnel DECON is to minimize worker contact with contaminants and to prevent spread of contaminants to clean areas. In most situations, personnel can use water and mild solutions to wash down. On smaller vessels and in cold environments, this may not be an option due to waste storage capabilities and the potential for the solution to freeze. In these cases, the preferred option is to attempt dry decontamination using clean rags or wipes to remove oil from the individual's clothing.

3.3.1 Initial Evaluation

The Great Lakes demonstrations (Yankielun, et al., 2012; Yankielun, et al., 2013) showed that most vessels, especially the tugboats, would have difficulty in handling crew DECON during an actual cold weather spill. Responders would need a temporary structure on deck as a Warm Zone to remove the contaminated personal protective equipment (PPE) to ensure oil is not tracked into the other living and piloting spaces. A research effort to investigate VOO protection and personnel DECON for cold weather identified the initial requirements (RDC, 2015).

3.3.2 Field Demonstration

From the August 2016 demonstration (Balsley, et. al., 2016), the RDC noted DECON line workers play a major role in performing efficient decontamination of responders if deck access/area is limited in cold weather. The National Strike Force (NSF) agreed that the existing DECON procedure was effective, but needed minor revisions. To ensure a safe and efficient process, instead of the coverall suit being ripped off with a knife, NSF recommended that the suit be rolled off carefully by a DECON line worker (Balsley, et al., 2016).

3.3.3 Decontamination Lessons Learned

The August 2016 demonstration also provided additional information for planning decontamination aboard vessels with limited deck space:

- Effective DECON can take place only if the DECON line workers are kept warm, well fed, and comfortable in between their work shifts; this allows them to remain as alert as possible.
- The prototype shelters used in the 2016 demonstration (see Fig. A-1 in App. A) proved to be too flimsy. Participants agreed that the shelters would not be able to withstand strong winds and cold temperatures, nor provide stable support to responders when they sit down. RDC recommends a sturdier structure for protection from the elements. Otherwise, DECON should be performed in the open air. Responders would have layers of warm clothing beneath the coverall that can still keep them warm during the DECON process. The shelters were effective in providing a clear physical barrier between the Hot Zone and the Cold Zone, providing responders awareness of the extent of their working zone. Whether or not a shelter is used, the RDC recommends that a DECON line worker be stationed at each DECON station to monitor the ingress/egress of workers, and to ensure that the Cold Zone remains contamination-free.
- Although deck space is at a premium, some space will need to be available for the storage of contaminated PPE (hazardous waste) until the ship returns to port and the contaminated PPE can be properly disposed of.

The DECON procedures that were proposed during the demonstration were modified to include the above recommendations, and the results are contained in Appendix A. DECON line workers were found to be especially helpful, since in cold weather, responders will have limited mobility due to additional cold-weather PPE, and, therefore, will be more susceptible to slips, trips, and falls. During the DECON procedure, the DECON line workers are expected to perform most of the DECON while the responders follow instructions.

4 RECOMMENDATIONS

The equipment deployed in the different oil-in-ice demonstrations exhibited varying utility for spill cleanup under the various ice conditions, with performance dependent on ice, wind, and weather conditions. Some of the tactics attempted in these demonstrations need to be refined and adapted to existing equipment and vessels. The RDC recommends further research in adapting cold weather personal protective equipment for easy decontamination. The RDC also recommends developing concepts of operation for UAS, UUV, and ROV technologies.

The RDC recommends additional exercises under extreme cold and harsh weather (for example, in higher waves and wind). This will further improve and build upon lessons learned regarding operational and tactical procedures; and equipment deployment, application, and design. These exercises also benefit response personnel in obtaining experience using the equipment and tactics under these extreme conditions.

A number of the systems demonstrated in the Great Lakes and the Arctic have the potential for use during an oil spill response; however, RDC recommends more research and/or additional demonstrations to improve the utility of these technologies. Specifically, the detection and surveillance technologies requiring more research include:

- UUV – Recommend further research on the selection of appropriate sensors. In addition, recommend research: to evaluate how decision-makers will use the data; to determine the proper data format and the refresh rate; and determine other operational specifications.

- Ice and oil radar – Recommend additional research to identify specific environmental conditions in which the oil detection algorithm that is provided in the radar's software, can be effective in ice.
- ROV – Recommend demonstrating ROV operation with manufacturer-specified 200-foot to 5,000-foot tethers in order to evaluate the full utility of the system.

The field demonstrations also revealed additional research and development is needed for technologies dealing with oil containment and recovery:

- Skimmer operation – Recommend developing techniques that can clear a hose if pumping is halted, the flow of liquid is intermittent, or a large amount of water gets into the system. Use of water-annulus systems to pump highly viscous oil require a significant amount of water that can become trapped in the hose or the skimmer and would have to be cleared to keep from freezing and disabling the flow.
- Ice Cage – Recommend further development to minimize the amount of small pieces of hardware used to assemble the ice cage, and to facilitate assembly while wearing cold-weather gloves. Recommend improving the design of the assembly stand to reduce the deck footprint.
- TST – Recommend further development to improve deck anchoring while reducing trip hazard, and minimizing the number of small pieces to facilitate assembly.
- Collection of oil under ice - Most current techniques assume that equipment and personnel can be deployed directly onto the ice. Recommend additional research to explore under-ice response options from vessels, when the ice is not strong enough to support personnel.

5 SUMMARY

The RDC conducted multiple demonstrations over a six-year period, involving hundreds of people and multiple organizations, to show how equipment can be used and deployed for a scenario with oil in ice. Multiple CG and commercial vessels were involved in these demonstrations. Some foreign participants including Canadian organizations were also involved. The demonstrations mixed researchers and manufacturers with CG and commercial responders. The result was the building of a knowledge base that is captured in Appendix B, as well as the knowledge that the participants absorbed and took home with them. These demonstrations will improve the responses to future oil-in-ice spills wherever they occur. CG responders and Federal On-Scene Coordinators (FOSCs) can utilize this information for planning and executing response actions.

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APPENDIX A. COLD WEATHER DECONTAMINATION PROCEDURE

A.1 Cold Weather Personal Protection and Decontamination Equipment

Table A-1 shows the dry DECON equipment that should be assembled for multiple responders transitioning out of a HOT zone and into a WARM zone. Table A-2 shows the typical cold weather PPE that a responder is expected to wear (in addition to a life jacket and inner layers for warmth) when working with oil spills in a cold-weather environment on a ship. A changing station (Fig. A-1 – A-3) should be placed near a hatch that the responder is expected to enter in order to leave the HOT zone. The conceptual station shown here is an enclosure designed for decontamination of workers removing asbestos.

Table A-1. Dry DECON equipment for one station.

Quantity	Item
1	Grayling 77" D-CON shelter (36" x 36" x 77") or 81" D-CON shelter (48" x 48" x 81") (Figure A-1) (Note: Other equivalent systems exist and should be chosen based on vessel arrangements and environmental conditions.)
1	77" or 81" Grayling D-CON pole set (8 poles)
1	Collapsible canvas stool (Figure 1)
2	Collapsible waste receptacles
3	Heavy duty storage bags, 73” x 36”
3	PCXM 55" x 45" x 73" plastic bags
2	Multiple large clear plastic zip-lock bags (Figures A-2-and A-3)
1	Misc. parachute cord (1 50-foot roll)
3	Misc. snap hooks (4-6 inch length)
1	5/16” 15ft black polyline w/ snap hooks
5	Hook & loop fabric cable ties
2	Green bungee cords (48 inch)
8	Terry cloth rags
3	Spray bottles of Simple Green cleaner (adjust quantity as necessary)
1	Pair scissors
1	Talon rescue knife
1	Triangular red safety LED lights
1	Hand-held mirror
6	Chem lights
6	Pairs disposable green vinyl gloves
1	Roll of contamination control zone marking tape
1	Push/Shop broom

Table A-2. Cold weather PPE for one responder.

Quantity	Item
1	Size XL/XXL Kleenguard coveralls w/ hood & boot
1	Hard hat
1	Hard hat windsock, ear/face
1	Clear plastic safety glasses
1	3M disposable ear plugs
1	Disposable respirator
1	Pair cotton utility gloves
1	Pair poly vinyl chloride (PVC) coated orange rubber (lined) work gloves
1	Pair safety boots
1	Pair non-skid boot/shoe covers, gray

Figure A-1. Prototype changing station with seat.

Figure A-2. Equipment secured ready for use attached to changing station.

Figure A-3. Hanging equipment also attached to changing station.

A.2 Setup Procedures

Table A-3 details the setup procedures for the DECON station for personnel.

Table A-3. Setup procedures.

Step	Setup Procedures
Step 1	Carefully consider safety, available deck space, visibility, and crew movement during cleanup operations and decide upon locations of the HOT zone, WARM zone, COLD zone, and DECON stations.
Mark Contamination Control Zone	
Step 2	1. Using the contamination control zone marking tape, mark off the HOT, WARM, and COLD zone boundaries. 2. Ensure the DECON shelter entry is clearly identified with lighting and/or taped pathway. 3. Determine the best foot traffic flow to prevent cross contamination.
Establish Station No. 1 - Gear Drop	
Step 3	Designate a location for responders to place contaminated gear, such as hand-held tools or PPE, as they begin the dry DECON process. 1. Place sturdy, 30-gallon hard plastic receptacles with sealable lids near shelter entry.
Erect the DECON shelter at Station No. 2 - Dry DECON	
Step 4	1. Erect the DECON shelter at Station No. 2 - Dry DECON, on a boundary line between the HOT and WARM zones. a. Sweep and clear the area where the shelters will be set up, then cut and lay a protective layer of plastic sheeting on the deck. b. Unfold the shelter and stand it vertically by lifting the top panel. c. Position and tension the poles into the corners in the recessed slots on the base and top panels. d. Place seat into position. e. Ensure that shelter entry is completely open but shelter exit has a flap that only the DECON line worker will open for the responders' admittance to the COLD zone. 2. Place disposable gloves, sorbent pads, and terry cloth rags in open plastic bags and attach to the outside walls of the shelter with Velcro strips within reach of DECON line workers. (Figure A-3) 3. Tie down shelter and all equipment.
Set up Station No. 3 - Redress and Monitoring	
Step 5	Establish Station No. 3 at the exit of the DECON shelter: 1. Set up portable lights. 2. Place a raised platform between shelter and the COLD zone to minimize oil tracking.
Set up Station No. 4 - COLD Zone	
Step 6	Establish Station No. 4 at the entrance to the clean area: 1. Set up portable lights. 2. Place sturdy, 30-gallon hard plastic receptacles with sealable lids near shelter exit.

A.3 Decontamination Procedures

In addition to all the equipment listed in Tables A-1 and A-2, responders will be aided by PPE managers and other responders as they proceed with the DECON procedure. At least one manager is needed inside the COLD zone to monitor and inspect individuals who pass through.

Table A-4. Decontamination procedures.

Station	Procedure
Station No. 1 - Gear Drop	1. Place handheld contaminated tools or equipment in the designated gear drop receptacle or area for re-use (e.g. unneeded load bearing equipment, wrenches, and screwdrivers).
Station No. 2 - Dry DECON	1. Before stepping inside the DECON shelter, request assistance from a DECON line worker. The DECON line worker will perform the following functions: a. Remove gross contamination on the surface of outer clothing and body worn PPE with Simple Green cleaner/equivalent and sorbent pads. Dispose of sorbent pads and any expended items in waste receptacle. b. Remove responder's hardhat and outer gloves; place them in designated receptacle. (Figure A-4) c. Using thin gloves for maximum finger agility, roll off the coverall. Start at the head of the responder and roll down to the shoulders. Direct responder to pull one arm out of the coverall sleeve and raise his/her arm up high. Roll the coverall sleeve down to the waist level. Repeat for the other arm. (Figure A-5) d. With both responder's arms raised and the coverall now rolled down below the waist level, direct the responder to sit on the stool inside the shelter with feet outside. e. Direct responder to raise his/her leg and remove the first boot cover. Proceed to roll the coverall off the leg. Direct responder to place clean leg inside the shelter and away from the HOT zone. Repeat for the other leg and dispose of the coverall into waste receptacle.
Station No. 3 - Redress/Monitoring	1. If necessary, put on clean disposable gloves and use sorbent pads/terry cloth rags to carry out spot cleaning on own body. DECON line worker stationed in the HOT zone will inspect responder and point out remaining contamination spots, if any.
Station No. 4 - COLD zone	1. Before taking the shelter exit: a. Request final inspection from a DECON line worker stationed in the COLD zone. b. Remove remaining contamination using terry cloth rags/sorbent pads, if any. Dispose of rags/sorbent pads into waste receptacle outside of shelter exit. c. Upon approval from DECON line worker, dispose of temporary gloves and footwear (if necessary) into waste receptacle outside of shelter exit in WARM zone. d. Step through the flap at the shelter exit and enter the COLD zone.
System Disposal	Place all contaminated materials and system components in the hard plastic receptacles with sealable lids and move them to a safe location for further waste processing upon arrival ashore.

Note: Special thanks to the National Strike Force and the Crew of CGC Juniper (WLB 201) for supporting the development of these procedures.

Figure A-4. Initial clothing removal.

Figure A-5. Using roll technique (2 views).

APPENDIX B. RECOMMENDED TACTICS FOR OIL-IN-ICE RESPONSE

These recommend tactics are for planners and responders and are formatted similar to those used by the US Environmental Protection Agency for inland response UMRBA (2006) and the Alaska Clean Seas manual (ACS 2015).

Each tactic sheet includes a summary of the tactic objectives and strategies that may be utilized, a picture or pictographic tactic description of a typical deployment configuration; and deployment considerations and limitations. The tactic sheet also contains resource information that summarizes the types and number of personnel needed for a standard shift (8-10 hours) and equipment recommended to implement the tactic as described. Specific tasks for each person are not provided. The equipment and personnel tables can be used to determine typical equipment and personnel needs; although actual equipment and personnel needs will be site and situation specific. The tables include the following information:

- “Equipment” is the list of equipment needed to execute the tactic.
- “Function” describes how the equipment will be used.
- “Pieces” is the number of each piece/item.
- “No. Staff/Shift” indicates the number of personnel needed per shift.
- “Set-up Time” is the time to make the equipment operational for its intended use at the spill site. In some cases, this is highly dependent on the environment and the specific piece of equipment being deployed.

B.1 DETECTION AND SURVEILLANCE

B.1.1 Aerostat

Use of an Aerostat or similar tethered balloon can enhance oil recovery by providing almost continuous surveillance. It adds an aerial observation advantage to an on-scene response vessel. It is useful to correlate aerial and marine observations that are taken at the same time and place.

Aerostat systems are not limited by duration, but are sometimes limited by weather. They also do not require full Federal Aviation Administration (FAA) approval for air space. In general, they must be kept at altitudes lower than 500 feet and not within 5 miles of airports. 14 CFR Part 101 - Moored Balloons, Kites, Amateur Rockets, Unmanned Free Balloons and Certain Model Aircraft covers the requirements.

Aerostat on Flight Deck

Deployment Considerations and Limitations

- The method of data format and supporting documentation are critical to be compatible with common operating picture.
- Video streams can be passed to line-of-sight receivers.
- Power and control are usually located on board a vessel.
- Type and number of sensors mounted in an Aerostat depend upon its lift capability, weather, and surveillance needs.
- Visual and infrared cameras are usually mounted; radars may be mounted to detect oil at extended ranges and communication systems used to extend coverage/range.
- Use in cold conditions can require additional helium; due to the increased density at the lower temperatures.
- Several sizes of Aerostat are well suited for oil spill surveillance. All have payload and supporting vessel limitations. Smaller systems deployed directly on the skimming vessel may identify oil locations and enhance recovery.
- Cost-effective, lightweight visual camera packages have difficulty seeing a person more than one mile away.
- Large systems can be used to coordinate the movement of several ships when deployed from a command vessel. If the multiple ships are spread out, higher-resolution systems are needed.
- Weights of deployment packages range from 800-1800 pounds, not including helium tanks.
- Systems can generally work in winds up to 50 knots; but control of the system is better at wind speeds less than 25 knots.
- Situational awareness of where the balloon and tether are located is essential due to wind shifts, crane operations, and other possible interferences on board the vessel.

Equipment and Personnel

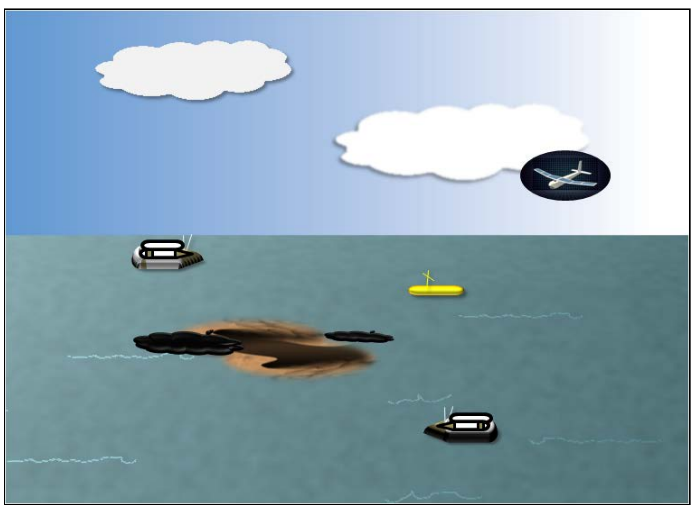
EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Command Vessel	Surveillance Platform	1	1-2	6 hours
Aerostat	Surveillance	1	3-4	2-3 hours

B.1.2 Small Unmanned Aerial Systems

Use of a Small Unmanned Aerial Systems (SUAS) can enhance oil recovery by providing real-time information on oil location and concentration to responders or back to the incident command post. The number and weight of sensors mounted on an SUAS will depend upon lift capability, endurance, and weather. Sensors may include cameras, infrared devices, and radar, as well as communications systems, such as radio links. The FAA regulations for SUAS are found at the following website: https://www.federalregister.gov/documents/2016/06/28/2016-15079/operation-and-certification-of-small-unmanned-aircraft-systems

There are additional vessel requirements, such as needing special permissions for CG vessels.

SUAS Tactic



SUAS Ready for Launch

Deployment Considerations and Limitations

- Several sizes of SUASs are capable of being used from 45 minute to several hours in duration. All have limitations for system payload, endurance and weather (wind and icing) in a cold environment.
- Deployment of SUASs is weather dependent. Potential icing conditions, low cloud cover, or high winds that exceed operational thresholds can ground these systems.
- The method of data format and supporting documentation are critical to ensure quality data is sent to the decision-makers.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Operational Vessel	Working platform	1	2-4	1-2 hours
SUAS	Surveillance	1-2	3	1-2 hours*

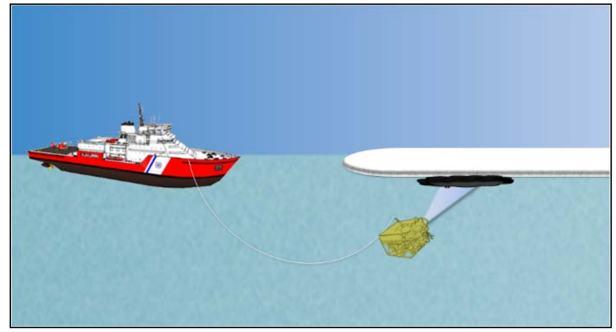
* depends upon SUAS and conditions

B.1.3 Remotely Operated Vehicle

This technique deploys a tethered Remotely Operated Vehicle (ROV) from a vessel near the ice edge to search for oil trapped under ice. It can also be placed down a hole through the ice if the ice is solid enough for personnel to safely stand on it. ROVs can utilize different sensor packages based on the needed data. Potential sensors include cameras, sonar, and fluorometers. Most sensors are configured in a looking-up position.

ROV in Process of Being Deployed Under the Ice

ROV Tactic (not to scale)



<u>Deployment Considerations and Limitations</u>

- Use of a ROV requires availability of some open water to ensure successful recovery.
- Care needs to be taken to ensure that cables are not tangled into propellers or bow thrusters. The cable may also be susceptible to damage from the ice and should not be dragged on the bottom in shallow water.
- Bright sunlight can help or hinder upward-looking sensors, depending on the conditions. For thin ice, the ROV may need to be deployed at a deeper depth to reduce glare. Lights may be needed on overcast days and at night.
- The weight of the system may necessitate the use of a crane; so the vessel selected should have this capability.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Vessel	Working platform	1	2	*
ROV	Search	1	2	<30 minutes

- Highly dependent upon location and type of ROV

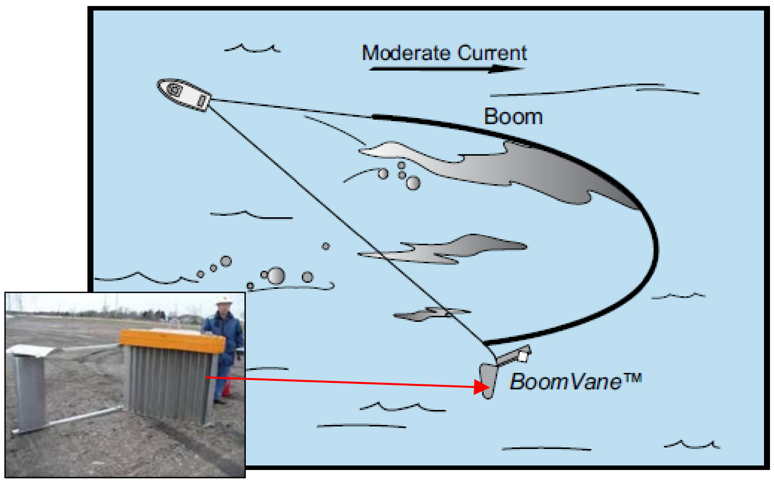
B.2 CONTAINMENT AND RECOVERY

B.2.1 Ice Edge Conditions

Ice Edge – Corralling and Boom Vane

Mechanical containment and recovery near the ice edge requires safe and efficient equipment operation. This tactic may involve skimmers deployed from a cutter or large vessel using a single davit or crane, deck-mounted excavator oil bucket/ boom assemblies, or similar configuration. The skimmers used will be the same as those for open water and broken ice depending on the conditions. Containment booms are deployed to intercept, control, and concentrate the oil. Most tactics usually focus on using two towing vessels; which enables maneuvering around ice floes. If the oil is in relatively open water close to the ice edge, a boom vane may be used instead of a second vessel to control the end of the boom and help keep the boom from connecting with the ice.

Tactic Diagram



Source: STAR Manual

Deployment Considerations and Limitations

- The boom vane technology may suffer limitations if there is broken ice near the ice edge that floats out into the capture boom and causes damage.
- Collisions with smaller pieces of ice in fast-moving waters may not be an immediate issue; but over time, they may accumulate in the containment system. This accumulation of ice within the boomed area would impart additional stresses on the system and may accelerate a failure mode.
- Operators should take special care in broken ice, as impacts by chunks of ice may damage, block, or interfere with the vanes, affecting control of the device and requiring suspension of operations until ice can be cleared.
- The vessel for deployment should be large enough to handle the boom and maneuver the Boom Vane.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/SHIFT	SET-UP TIME
Operational Vessel	Working platform	1-2	2-4	1-2 hours*
Tugboat	Working platform	1	2-3	<1 hour
Boom and boom vane	Containment	1-2	2-4	< 1 hour
Skimmer	Recovery	1-2	2-4	< 1 hour

* depends upon equipment and conditions

Ice Edge – Herding

Herding using a fire monitor or water cannon move spilled oil towards or along the ice edge to a collection point and-or helps concentrate the oil near a skimmer. Under some conditions these can also be used to control the movement of ice.

Deployment Considerations and Limitations

- Direct the stream of water at least 10-20 feet from the oil so that the induced surface current and not the direct water stream moves the oil. Care should be taken not to send water directly into the ice or with too much force. This could push the oil under the ice.
- Care to prevent freeze-up of the monitor/water cannon is needed when the system is off.

Herding Oil into Ice Pockets

- Equipment placed over the side, such as a pump suction hose, can be exposed to ice that can damage or disable the equipment.
- If the ice is not clearly defined, deploying a boom alongside the ice edge could help concentrate the oil.
- One drawback to a self-contained fire monitor pack is its weight, which limits its use to larger vessels and requires a crane to maneuver the package.
- Use of fire monitors and hoses already installed on vessels should generate similar results to the above fire monitor pack.
- Bow mounting the water cannon may make vessel handling and positioning easier. Stern units should only be used as a last resort.
- Moving larger pieces of rubble ice with the water jet may be difficult.
- Multiple vessels with monitors would be more effective at herding oil in open water than a single vessel.
- Use of a boom on the outboard side of the vessel could help concentrate any oil.

Equipment and Personnel

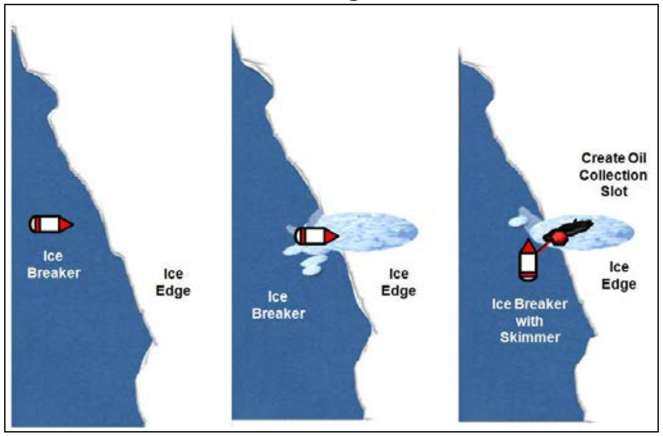
EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Vessel	Working platform	1	2	*
Fire Monitor	Herd oil	1	2	<1 hour

* highly dependent upon equipment

Ice Edge – Slotting

There may be many instances when the ice can be managed using an icebreaker to gain access to the oil or to keep ice away from the oil. Where the oil is moving towards a solid ice sheet, it may be possible to trap the oil by using the icebreaker to create a slot in the ice to isolate the oil from wind and current. Once the slot is created, a skimmer can be deployed to recover the oil from the slot.

Tactic Diagram – Vessel Being Used to Create Collection Slot Allowing Oil to Concentrate



Deployment Considerations and Limitations

- In broken ice conditions, ice that is moved aside may shift back into place depending upon wind and wave conditions.
- The window of operations may be limited. Shifting ice can easily entrain and trap the oil under the ice; so caution should be taken not to disturb the ice.
- Potential tactics include using vessels to move or deflect ice and creating collection slots for ice-covered oil to re-surface. Consider how the ice and currents are moving so that any oil is deflected into the slot.
- The vessel used must have the correct ice classification and operator expertise before using this technique. Multiple vessels could be involved in this tactic, some of which may not have skimming capability.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Ice-capable Vessel	Working platform	1	2	*
Skimmer	Oil recovery	1	2	<10 minutes

* depends upon location

B.2.2 Broken Ice Conditions

Broken Ice – Skimming

Mechanical recovery in broken ice is limited by the ability of the skimmer to encounter and remove spilled oil in the presence of the broken ice and to function effectively under extremely low temperatures.

This tactic may involve skimmers deployed from a cutter or large vessel using a single boom or crane, excavator oil bucket/boom assemblies, or similar configuration. The vessel must try to get as close to an area of collected oil as possible and use the boom/crane to place the skimmer in an area not occupied by ice. It must be carefully monitored so that it is not crushed by the bigger ice floes. If the oil is in pools separated by ice, the skimmer may need to be lifted from the surface and repositioned to another pocket of pooled oil.

Skimmer Deployed in Broken Ice

Deployment Considerations and Limitations

- The vessel chosen should have the appropriate ice classification and staffing to perform operations in broken ice.
- The vessel should be able to handle temporary storage bladders or containers.
- Hydraulic hoses and recovery hoses may be susceptible to damage if dragged over or through ice.
- Long lengths of hose running over the deck may need to be heated to prevent freezing even when using non-collapsible hose.
- Pieces of ice can block the oil from reaching the skimmer inlet.
- Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs.
- The use of an oil recovery bucket/boom assembly securely mounted to the deck of a barge and pushed by a towboat works well in these circumstances in terms of maneuverability.
- In contrast, skimmers that use a tether system and that are deployed over the side may present challenges in terms of maneuverability but do not require an extended crane to be deployed.
- In greater than 70% concentration, ice is a significant impediment to skimming, with most skimmers having dramatically lower rates and efficiencies in the denser ice.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	MOBILI-ZATION TIME	DEPLOY TIME
Operational Vessel	Working platform	1	2	*	1-2 hours
Tugboat	Maneuvering platform	Optional	*	*	*
Skimmer	Recovery	1-2	2-4	*	<30 min.

* depends upon location

Broken Ice – Ice Cage

Skimmer performance in broken ice conditions may be improved by the addition of an ice cage to deflect the ice away from the skimmer while letting the oil through. The figure below shows the ice cage designed to work with the DOP-Dual Helix skimmer as deployed from a USCG buoy tender.

Deployment Considerations and Limitations

- The vessel chosen should have the appropriate ice classification and manning level to perform this. The vessel should also be able to handle temporary storage of collected oil.
- Skimmer deployment may be difficult. Hydraulic hoses and recovery hoses may be susceptible to damage if dragged over or through ice.

Skimmer with Ice Cage Being Deployed from a Buoy Tender

- The cage may be susceptible to ice damage in spite of proper handing.
- Pieces of ice can still block the oil from reaching the inlet so the skimmer/cage combination may need to be deployed in multiple pockets.
- Adequate hoses and heating systems may be needed on certain configurations when reaching away from the vessel or if recovering a large amount of water.
- Long lengths of hose running over the deck may need to be heated to prevent freezing.
- Excavators, cranes, or booms should be securely fastened to decks by welding or stabilizer legs.
- The use of an oil recovery bucket/boom assembly securely mounted to the deck of a barge that is pushed by a towboat works well in these circumstances in terms of maneuverability while providing deck space and storage.
- In contrast, skimmers that use a tether system from the vessel and that are deployed over the side may present challenges in terms of maneuverability.

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Operational Vessel	Working platform	1	2	1-2 hours
Tugboat	Maneuvering platform	Optional	*	*
Skimmer/ice Cage	Recovery	1-2	2-4	<90 minutes

* depends upon location

Broken Ice – Herding and Ice Management

Herding is designed to move the oil slick into an area where it can be burned, contained, or recovered. The herding process in broken ice is similar to herding at the ice edge. The main difference is that ice may be herded along with the oil. An additional use is to aid in the movement of broken ice on the water surface, keeping the ice from interfering in oil recovery operations.

Herding is usually done with a fire monitor that can move oil from a fixed location into a preferred area. Oil can be trapped in small spaces between bits of rubble ice, making it inaccessible for burning or collection by oil skimmers. Ideally, oil should be herded towards a more open area that is reachable by responders to conduct their recovery operations. Use of a robust skimmer is needed at the collection point.

Certain types of skimmers can also be used to manage the ice, as shown in the figure below with a carne-mounted bucket skimmer.

Skimmer Maneuvering a Piece of Ice

Deployment Considerations and Limitations

- The water stream should be directed at least 10-20 feet from the ice so that the induced surface current, and not the direct water stream, moves the oil. Care should be taken not to send water directly into the ice or with too much force that could push the oil under or onto the ice. A direct water stream will disperse and/or emulsify the oil.
- Care for preventing freeze-up should also be taken if the system is off.

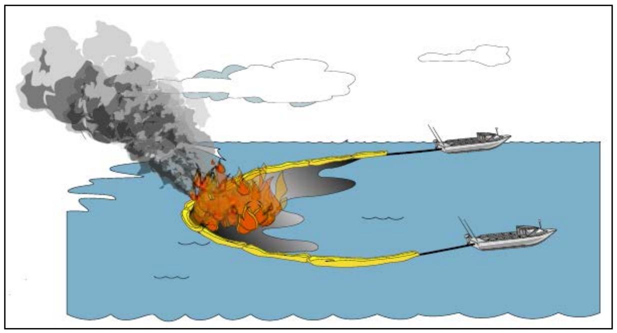
Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Vessel	Working platform	1	2	*
Fire Monitor	Herd oil	1	2	<1 hour

* depends upon location

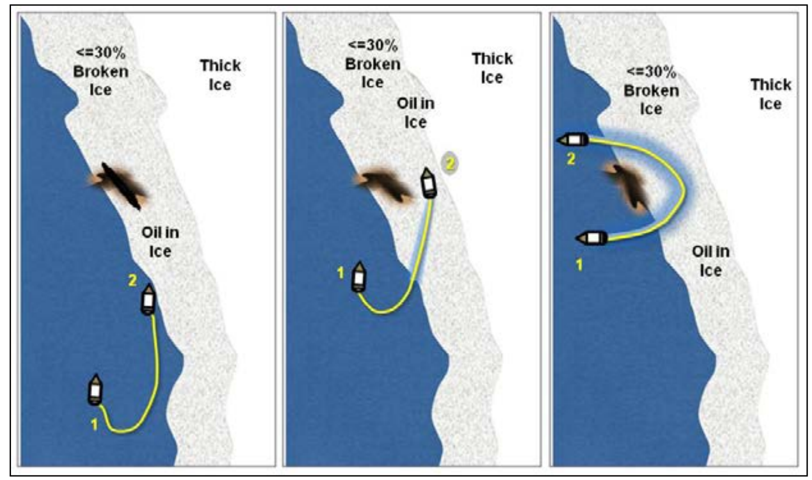
B.3 IN-SITU BURNING

In-situ Burning (ISB) is a technique to remove oil from the surface of the water before it reaches the shoreline. Vessels must capture the oil and tow it to a safe location (defined by the Federal On-scene Coordinator (FOSC) with respect to water depth, smoke plume, and distance from population and other responders) while moving at less than 1 kt. In open water, two response vessels are recommended to tow the fire boom between them in a "U" configuration (see figure below from STAR; B/W version available from ACS).



In-situ burning may also be used in broken sea ice under certain conditions. In circumstances where higher ice concentrations isolate the oil and prevent it from spreading (usually in ice concentrations greater than 70%), burning may be able to remove a high percentage of the slick (potentially up to 90%). However, broken ice conditions may complicate vessel operations and fire boom deployment if booming is necessary to concentrate the oil. During spring break-up, oil may accumulate in melt pools, while subsurface oil slowly migrates to the surface through brine channels and cracks in the ice. At break-up, this pooled oil will spread into the broken ice. During freeze-up, spilled oil may be contained by new thin or slush ice. When collecting oil in broken or brash ice, ice may be collected along with the oil. Vessels should do their best to avoid amassing a large number of ice pieces. Use of a "J" formation in deploying the boom may make it easier for the vessels to control the amount of ice captured (see figure below) by allowing for quicker release of oil from the boom. The boom can be converted to a "U", once free of the ice field.

Tactic Diagram – Colleting Oil for Burning



Approach **Capture** **Remove**

The general tactics and safety precautions for ISB on open water apply to ISB in broken ice. That is, ISB can only be used if the wind is blowing away from populated areas and if the collected oil forms a thick enough layer to allow for ignition. Oil that gathers inside the boom is moved to a location away from the main spill slick where it is ignited. By controlling the speed of the vessels, the rate of the burn can be increased, decreased, or even extinguished. Any residues left in the boom after the burn must be recovered by conventional means either by skimmers or manually.

Deployment Considerations and Limitations

- The deployment, logistics, and safety considerations for ISB on open water generally apply to ISB in broken ice.
- The boom may be deployed from either a staging platform, such as a barge, or the towing vessels. However, in either case a very large deck space is necessary to stow the boom before deployment.
- Deployment typically involves laying the boom on deck and then towing the length of boom into the water from the deck. Then the vessels move to a start position, where another tug retrieves the other end of the boom.
- Depending upon boom weight, environmental conditions, and staffing levels, a crane or lifting boom is typically necessary in order to recover the boom not otherwise destroyed in the ISB process.
- Two vessels of sufficient horsepower with ice-breaking capability are required for effective deployment and manipulation of the boom.
- 40–50% broken ice coverage with floes no larger than 5 feet appears to be the upper limit for carving out a sufficient oil/ice mixture for in-situ burn.

Collecting Ice which could Potentially Include Oil

Equipment and Personnel

EQUIPMENT	FUNCTION	PIECES	NO. STAFF/ SHIFT	SET-UP TIME
Control vessel	Boom deployment and retrieval	1	2	1-2 hours
Tugboat	Tow and manage boom	1	2	1-2 hours
Crane	Recover boom	1	1	1-2 hours
Fire Boom	Containment, ISB	1	2-4	1-2 hours
Ignition system	Burn collected oil	10	1	1 hour
Fire suppression system	Control burn if necessary	2	*	*

* depends upon location